

## Description

### Methods for Automatically Identifying Microorganisms Collected on a Carrier

The invention concerns methods for automatically identifying microorganisms collected on a carrier that are particles, airborne or present in water, in the form of fungal spores and bacteria.

As is known in the art, the identification of airborne particles or particles present in water is done by collecting these particles on a carrier. This carrier is advantageously positioned in a channel or at the end of a channel for supply air or water. In this connection, the carrier is a filter or a body with a coating of an adhesive. After collection, the particles are incubated on culture media in microbiological laboratories. After several days, an analysis of the colonies obtained in this way can be done. The colonies that all can be traced back to only a single collected germ are coarsely preexamined manually in regard to color, shape, and structure. A more precise determination of the species of germ is possible only after their individualization as well as growth tests and metabolic tests. This usually takes several weeks. Also, the identification of these colonies is done manually.

The invention set forth in claim 1 has the object to automatically identify microorganisms collected on a carrier that are particles, airborne or present in water, in the form of fungal spores and bacteria.

This object is solved by the features listed in claim 1.

The method for an automatic identification of microorganisms collected on a carrier that are particles, airborne or present in water, in the form of fungal spores and bacteria is characterized in particular in that certain fungal spores and bacteria are

5 automatically identified as their species and indicated and/or saved. In this way, the  
method is suitable advantageously for monitoring the atmosphere inside and  
outside of buildings, wherein the carrier is arranged in the supply air or the  
atmosphere. However, the method is suitable also for monitoring flowing or standing  
10 water, wherein the carrier is moved in the water or placed into flowing water. As a  
result of the automatic identification of the particles on the carrier surface, which  
particles are in the form of fungal spores or bacteria, it is possible to react quickly  
when harmful microorganisms are present as particles in the form of fungal spores  
and bacteria. In known methods, it is necessary to first cultivate cultures and to  
15 manually identify these cultures. This takes several days so that only after a  
relatively long period of time reliable results are available. A fast reaction is not  
possible in this way. Advantageously, the particles are automatically identified by  
the method of the present invention. The special advantage resides in the quick  
identification of the presence of fungal spores and/or bacteria and the identification  
20 of the species of certain fungal spores or bacteria in accordance with the contents  
of the classification system. For this purpose, the carrier surface with the collected  
particles is recorded, inclusive of the particles, and the image of the carrier surface  
is digitalized. This color image, a grayscale image derived therefrom and/or a  
silhouette image transformed therefrom serves for determining objects within the  
25 image. By means of a model-based comparison method, the individual objects are  
advantageously identified, if present. By means of at least one feature  
determination, a case-by-case classification of the objects is carried out. The  
determined objects are advantageously indicated and/or saved as a species. The  
result is a documentation of the results that are available anytime as the actual  
result and, subsequently, as a history.

A further important advantage of the method according to the invention resides in  
that when undetermined and thus non-classified objects are present, they are  
indicated and/or saved as a color image and/or grayscale image and/or silhouette  
image. In this way, there is the possibility of identifying these objects manually or

to discard them. In the first case, these manually identified objects are added as a new case with a determined class in the classification system. The classification system is thus continuously expanded so that the results of the method can be refined.

5 In this way, a method for automatic identification of microorganisms collected on a carrier that are particles, airborne or present in water, in the form of fungal spores and bacteria is provided that can be continuously expanded on. This is based on the case-by-case classification system that is upwardly open. Accordingly, the different forms of appearance of the spores or bacteria in their life cycle can also be  
10 incorporated into their automatic identification. During their life span, they change their appearance and their size in accordance with the prevailing ambient conditions. Accordingly, different variations of spores and bacteria of each species exist and can be automatically detected by using the method.

Also, the particles deposit in different positions on the carrier surface so that  
15 different geometries of each species can be recorded. The method is characterized advantageously also in that these geometries differing with regard to their position can be incorporated into the identification of the spores or bacteria.

Advantageous embodiments of the invention are presented in claims 2 to 9.

Advantageously, in accordance with the further embodiment of claim 2, in addition  
20 to the species the number of identified objects of said species is indicated and/or saved also. In this way, it is possible to also introduce threshold values wherein, for example, an alarm signal is triggered not only when presence is detected but also upon surpassing a certain number of certain particles.

In accordance with the embodiment of claim 3, advantageously the number of  
25 objects that are not identify are counted also so that in the case of a manual

identification of these particles immediately their count is also indicated and/or saved. Another repetition based on the expanded classification system is prevented. It is possible to react more quickly to dangerous situations.

5 In accordance with the embodiment of claim 4, errors are advantageously purged from the image of the carrier surface with the airborne particles after digitalization and the image is standardized. During standardization, colors and differences of the images are advantageously compensated.

10 In accordance with the embodiment of claim 5, further features for the identification of the objects are the shape, the texture, or the structuring of the objects in the color image and/or in the grayscale image. In addition to the outer shape, visually discernable features in the interior of the objects are also incorporated into the identification.

15 The embodiment of claim 6 advantageously enables that objects that overlap in the images can be detected with the method according to the invention. Such objects are at least partially overlapping one another. In the case of a large number of particles on the carrier, such arrangements of particles are very likely. For this purpose, the objects that are only partially visually discernable are individualized and compared to objects of the classification system. The objects that are only partially visually discernable are indicated and/or saved. Moreover, the correlated  
20 similar objects of the classification system are indicated and/or saved in this connection. At the same time, advantageously the level of congruence is also indicated and/or saved so that by means of a manual comparison the identification can be confirmed or discarded. The number of identified objects rises so that the result of the automatic identification is significantly increased.

25 In accordance with the embodiment of claim 7, the image of the carrier surface with the collected particles is recorded as a color image at least once two-dimension ally,

sterically and/or three-dimensionally. By means of multiple two-dimensional images of the carrier surface with different depth of field, it is possible advantageously to determine also three-dimensional features of the objects by means of two-dimensional images. The depth of field depends on the adjusted lens width, the focal length, and the aperture. The basis is that when adjusting the lens of the camera to a certain image width, only object points within a certain object width are reproduced in the image plane. The images of object points with smaller object width are produced behind the image plane, and those of the points of greater object width are generated in front of the image plane. A sterical image is created by utilization of holography. In this connection, the hologram can advantageously be recorded by means of different image scales with a camera, for example, in the form of a digital camera. A further advantage resides in that the hologram can be represented with a plane wave at greater or smaller wavelength so that the images are also greater or smaller.

In accordance with the embodiment of claim 8, advantageously additional objects can be determined by dyeing the carrier surface. Such objects are not recognizable, or only with errors, under normal conditions without dyeing.

In an embodiment according to claim 9, the identification of objects is further improved. A first determination is realized by images of the undyed surface of the carrier. By means of subsequent dyeing, further optical properties of the object can be made visible. A subsequent automatic determination increases the degree of identified objects significantly.

One embodiment of the invention will be described in the following in more detail.

A method for automatic identification of microorganisms collected on a carrier that are particles, airborne or present in water, in the form of fungal spores and bacteria will be explained in the following in more detail.

In a first step the carrier surface with the collected particles is recorded as a color image and, advantageously, is simultaneously digitalized. The image is recorded by a device with image enlargement, for example, a microscope with a digital camera, so that for further processing immediately a digitalized image of the carrier surface with the particles is available. This image, in accordance with a first embodiment, is transformed into a grayscale image and, in accordance with a second embodiment, is transformed into a grayscale image and, subsequently, converted into a silhouette image by at least one transformation step. When particles are present, a grayscale image is generated with resulting full-surface labeled objects of one grayscale and a background having a different grayscale. By means of a model-based comparison method, the objects are identified in the grayscale image and/or in the silhouette image. The model in the model-based comparison method is comprised of a quantity of points that describe the contour of the object and the corresponding directional vector. In the past, models such as circles of different size, elliptical shapes of different size and orientation, and rectangles of different size and orientation and having rounded corners have been developed. During the comparison process, the transformed model is compared to the image at any location and a value of similarity between model and image points is generated. The standardized point product of the directional vector of the transformed model and of the vectors is used for generating a comparative value. The standardized level of similarity has the property that it returns a value smaller than one as a result of the comparison. A result of one is produced when model and object are congruent. Moreover, the result corresponds to the proportion of the model that is visible within the image. The model can also be rotated for improving the result so that a result is produced that is greater than the previously determined result and is identical/smaller than one.

The identification of the objects in the grayscale image and/or silhouette image enables marking of the contours of identified objects in the color image and/or in the grayscale image. By means of this marking, the shape, texture, and structure of the

identified objects are determined as features in the color image and/or grayscale image. Moreover, based on this, parameters of determined objects can be advantageously calculated also. Such parameters are inter alia surface areas, dimensions in different directions, and the circumference so that additional comparison possibilities are provided. The features form the basis for a subsequent case-by-case classification of the identified objects. The objects that are classified and identified in this way are indicated and/or saved as species, name and/or code.

Determined and non-classified objects are also indicated and/or saved as color images and/or grayscale images and/or silhouette images. Accordingly, these objects can be subsequently either discarded or added as a new case with determined class to the classification system. On the one hand, in this way the saved knowledge in the classification system is expanded and refined, and, on the other hand, the non-classified objects are documented so that later processing can be done also.

In one variant of the embodiment, the objects are additionally counted. This can be done with the classified and identified objects as well as with the non-classified objects. The indication and/or saved values are supplemented by the count, respectively.

For improving the image of the carrier surface with the airborne particles, errors can be purged from the images after recording and digitalization and the images can be standardized by means of image preprocessing.

In a further embodiment, the overlapping particles on the carrier surface are also incorporated into the method for automatic identification of particles collected on a carrier. In this connection, in a first image analysis overlapping particles of the color image or of the grayscale image are separated, removed as objects from the color image, and saved as a partial image. In a second image analysis the overlapping

objects of this partial image are separated from another and again saved as a partial image. Features of the objects that can be identified are determined in accordance with the embodiment and, based on these determined features, a comparison with objects in the classification system is carried out. Missing areas can be supplemented in that a determination of these objects is also provided. Advantageously, the original and individualized object, the identified object that has been determined by the supplement, and the level of congruence and thus of the magnitude of the supplement for a manual identification is indicated and/or saved for documentation purposes.

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In another embodiment, the carrier surface can be dyed for improving the identification of the particles. The dyeing action can be done prior to recording as well as after recording an image.

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